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College of Science and Engineering

What is the role for trees and vegetation in reducing air pollution?

Prof. Paul S. Monks

Perspective ….

- Air Quality Research Scientist

- Chair of the Government Science Advisory Committee for Air Quality (Defra, AQEG)

Department
for Environment
Food & Rural Affairs

- Member of Defra Science Advisory Council

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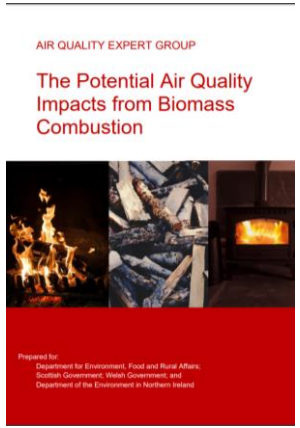
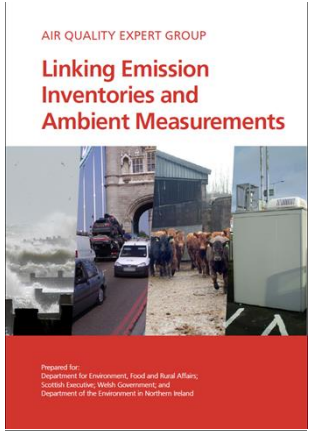
Department for Environment Food & Rural Affairs

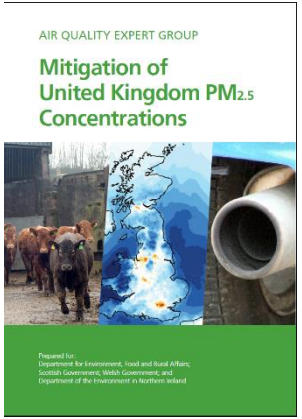
Air Quality Expert Group

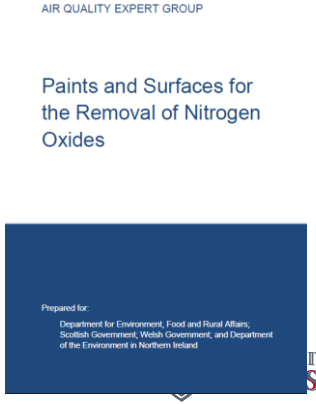
- The Air Quality Expert Group (AQEG) is an Expert Committee to Defra that provides independent scientific advice on air quality, in particular the air pollutants contained in the Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland and those covered by the EU Directives on Ambient Air Quality.

- Specifically AQEG gives advice on levels, sources and characteristics of air pollutants in the UK. It does not advise on health impacts or air quality standards.

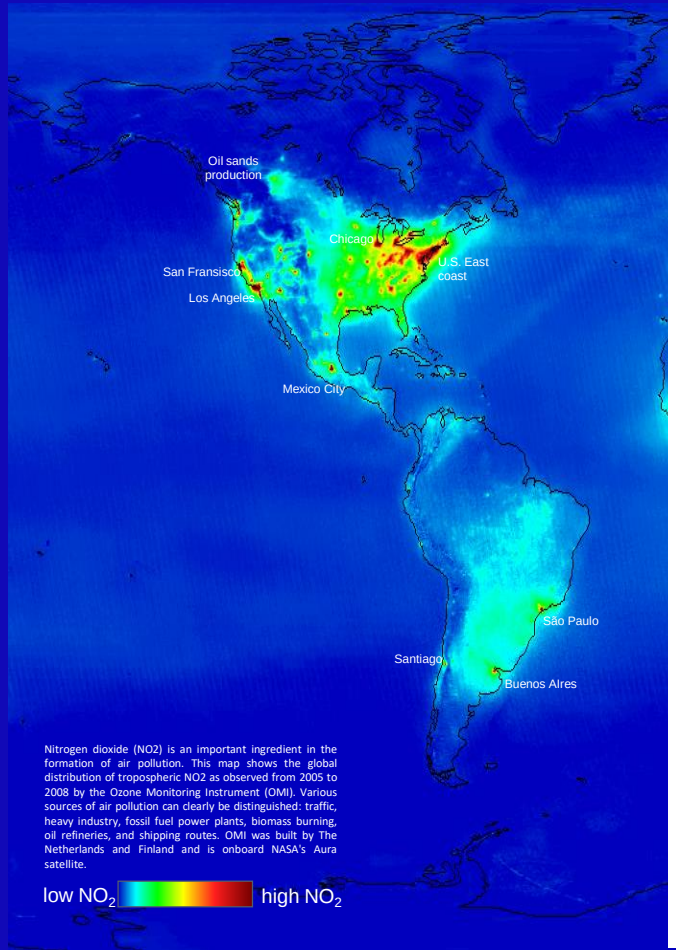








Air Pollution



Environment › Pollution

Air pollution 'will become bigger global killer than dirty water'

OECD report says pollution will become biggest cause of premature death, killing an estimated 3.6 million people a year by 2050

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Fiona Harvey
guardian.co.uk, Thursday 15 March 2012 17.44 GMT

A larger | smaller

Beijing, China, which is one of the countries likely to be worst hit by pollution-triggered deaths in coming decades. Photograph: David Gray/Reuters

Urban air pollution is set to become the biggest environmental cause of premature death in the coming decades, overtaking even such mass killers as poor sanitation and a lack of clean drinking water, according to a new report.

Both developed and developing countries will be hit, and by 2050, there could be 3.6 million premature deaths a year from exposure to particulate matter, most of them in China and India. But rich countries will suffer

Environment
Pollution · Climate change · Carbon emissions

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Air pollution could become China's biggest health threat, expert warns
Leading respiratory disease specialist warns of consequences if government fails to monitor and publicise the dangers of smog

London air pollution at record high

Air Quality

"Despite considerable improvements in past decades, air pollution is still responsible for more than 400 000 premature deaths in Europe each year. It also continues to damage vegetation and ecosystems."

EEA (2015)

BIRMINGHAM

WORKING TOWARDS A HEALTHY CITY, HEALTHY PLACE

Birmingham City Council

EFFECTS OF AIR POLLUTION

IN 2010/11

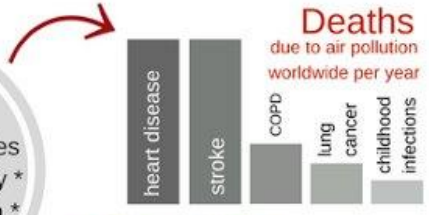
891

DEATHS

linked to man-made air pollution

LINKED TO

* Cancer * Diabetes * Asthma * Obesity * Stroke * Dementia * Heart Disease *



affects the **vulnerable** and **deprived** areas most

exposed to 21% higher levels of pollution

33.9 % travel to work by car

LINKED TO

* Low birth weight * premature deaths * still births* infant deaths * organ damage*

CHILDREN in HIGH POLLUTION AREAS are 4x more likely to have reduced lung function when they become adults

BUS & TAXI DRIVERS are exposed to **3x more** pollution than anyone else

Data sourced from: Public Health Outcomes Framework (PHE), "Every Breath We Take - the lifelong impact of air pollution" (2015 RCP & RCPCH), Marmot Cold Homes. Active Travel Survey 2015

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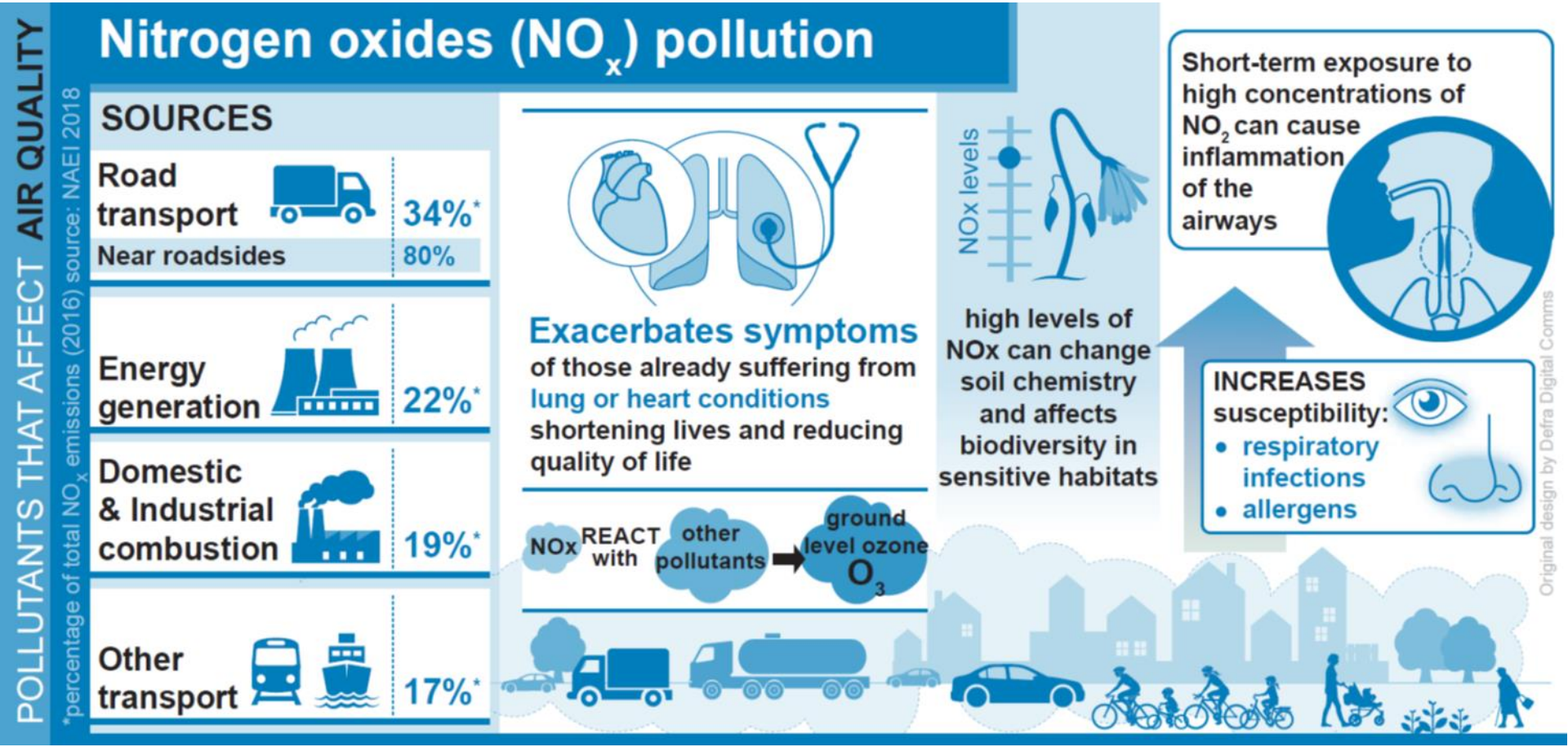
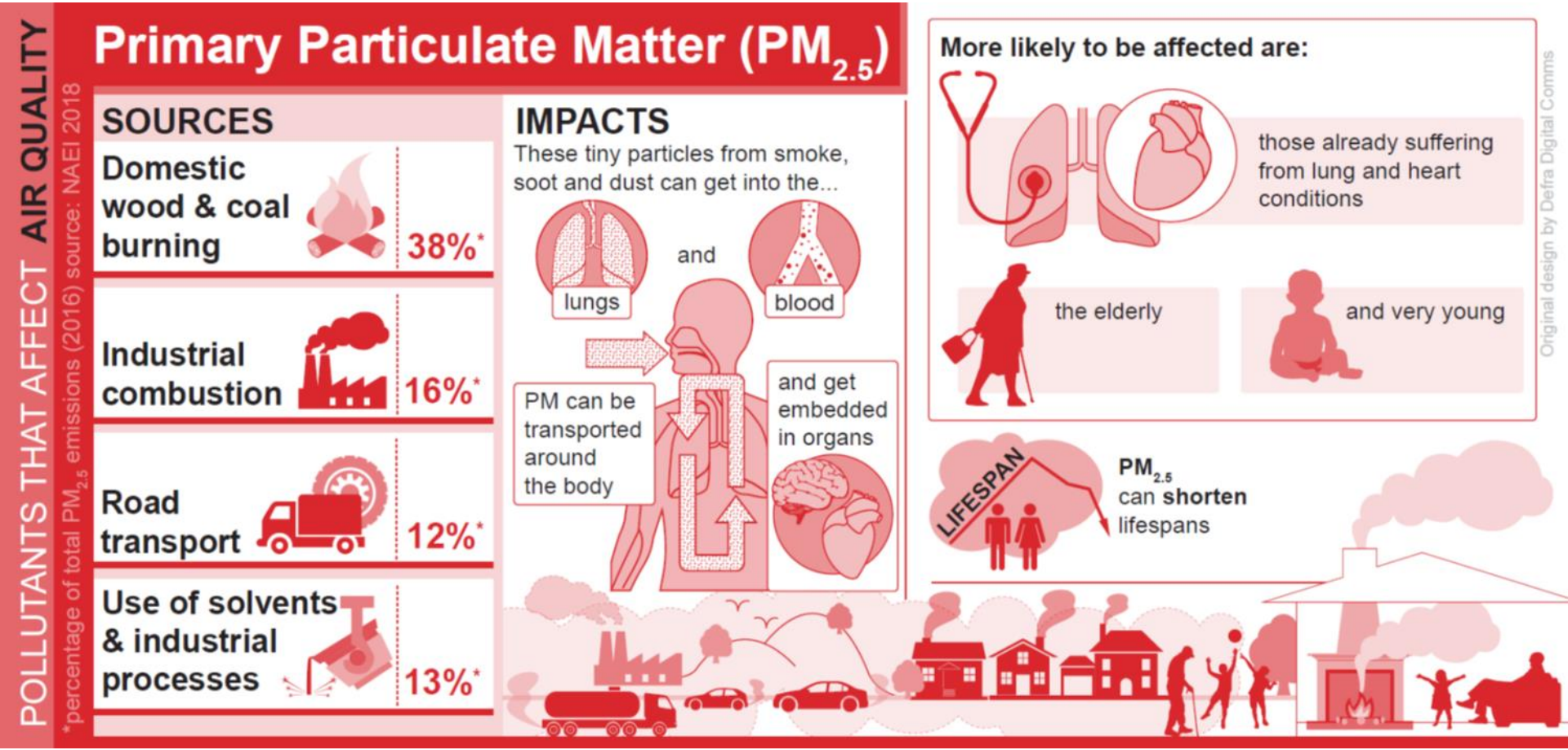
What is the impact of Air Quality?

AQ has implications for a number of contemporary issues including:

- Human health,
  (e.g. respiratory, cancer, allergies…),
- Eco systems (e.g. crop yields, acidification / eutrophication of natural ecosystems),
- National heritage *(e.g. buildings),*
- Regional climate *(aerosol and ozone exhibit a strong regionality in climate forcing).*

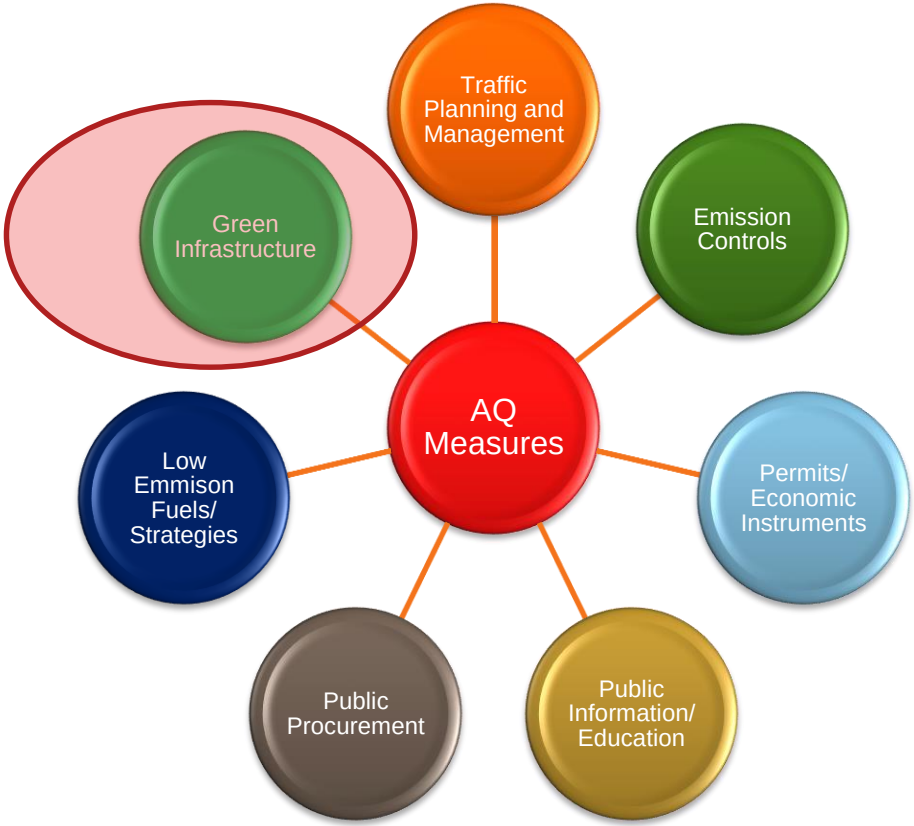


The Pollutants …



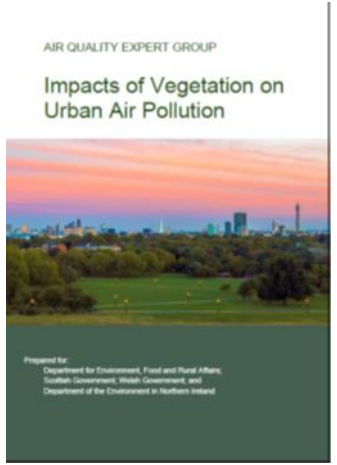
The Pollutants …

Mitigation and solutions …



- Costs, benefits
- Who pays?
- Technical, non-technical

Impact of Vegetation on Urban Air Pollution



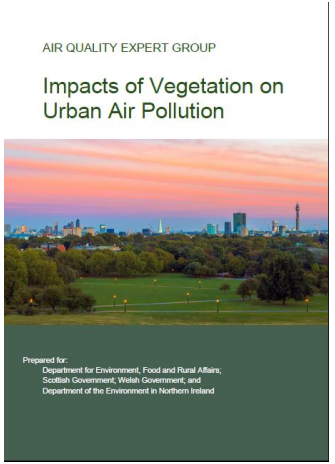
- *Is there definitive observational evidence of the effectiveness of urban vegetation in mitigating air pollution?*
- *What role does vegetation and its effects on air pollution play in integrated urban planning and policy?*
- *Are the data and models to quantify effects of urban planting schemes on air quality in the major cities of the UK generally available?*

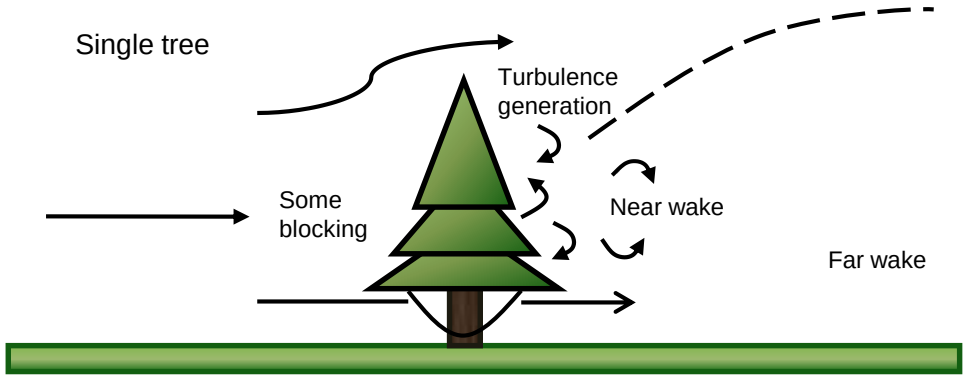
Background

The urban landscape, buildings, roads, parkland, gardens….there are opportunities to change the surfaces

But space is limited and in general the scope for additional vegetation in the urban setting varies hugely and maximizing the benefit for the population should be the objective

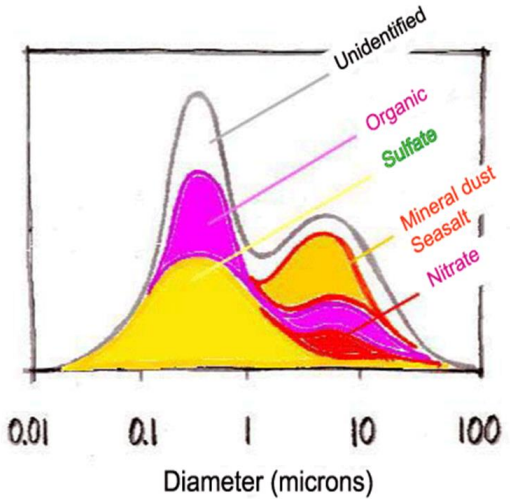
What do trees do …

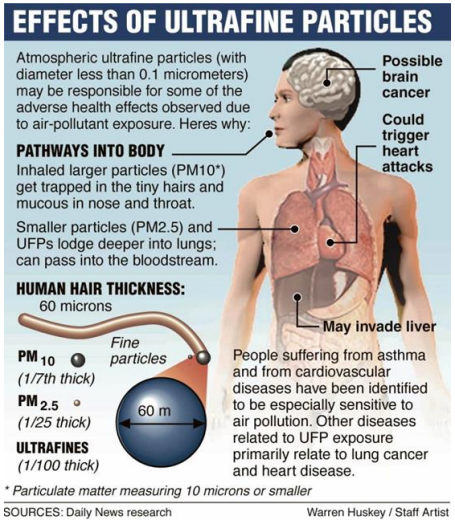


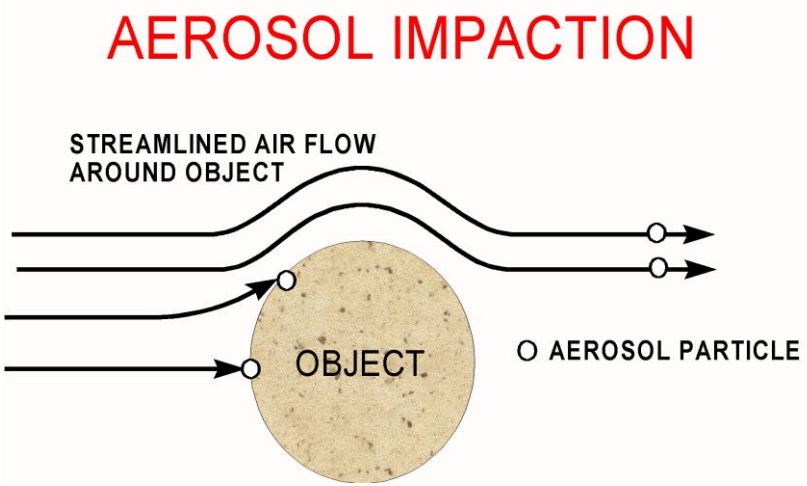


a) Aerodynamic – trap vs. disperse (barrier)
b) Deposition to the tree (leaf) surface

Particles – Capture and Dispersion







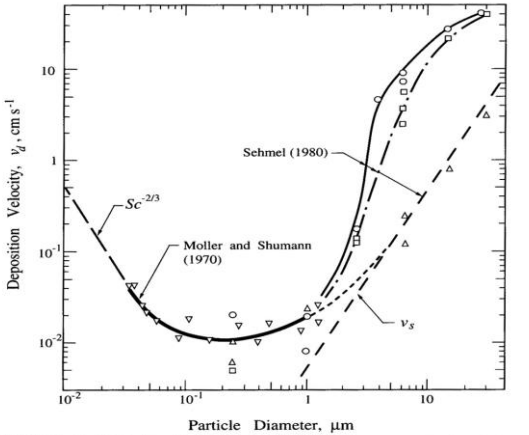
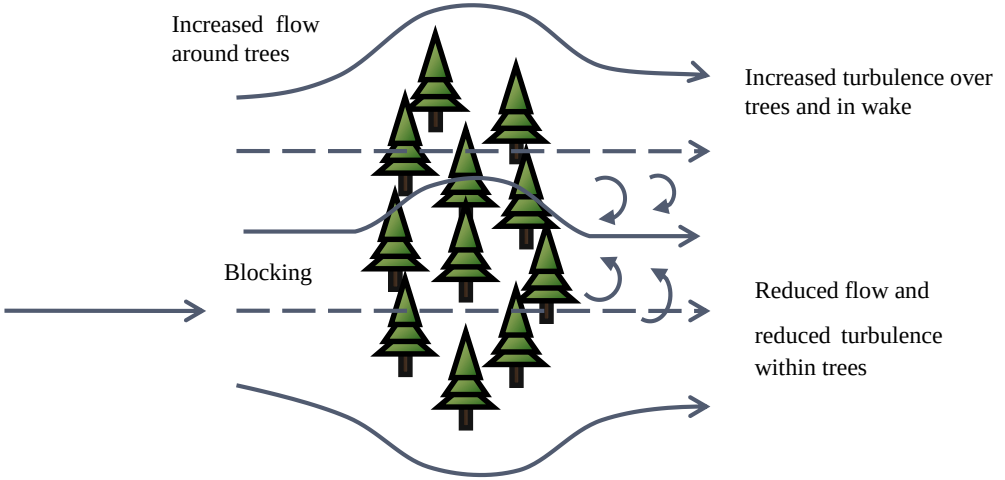


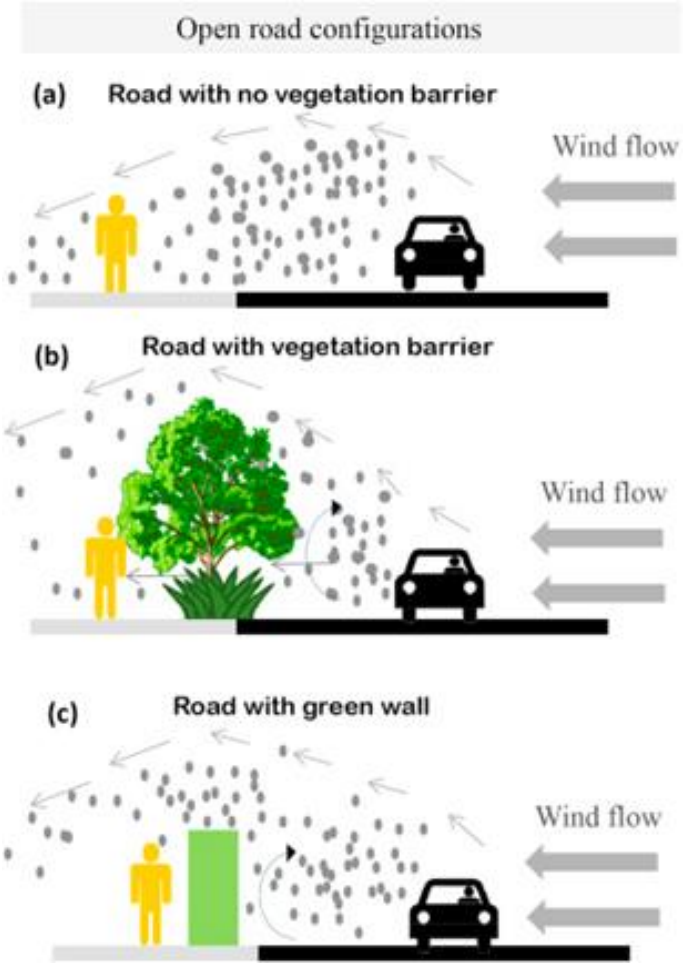
FIGURE 19.3 Particle dry deposition velocity data for deposition on a water surface in a wind tunnel (Slinn et al., 1978).

Particles come in a range of sizes and composition

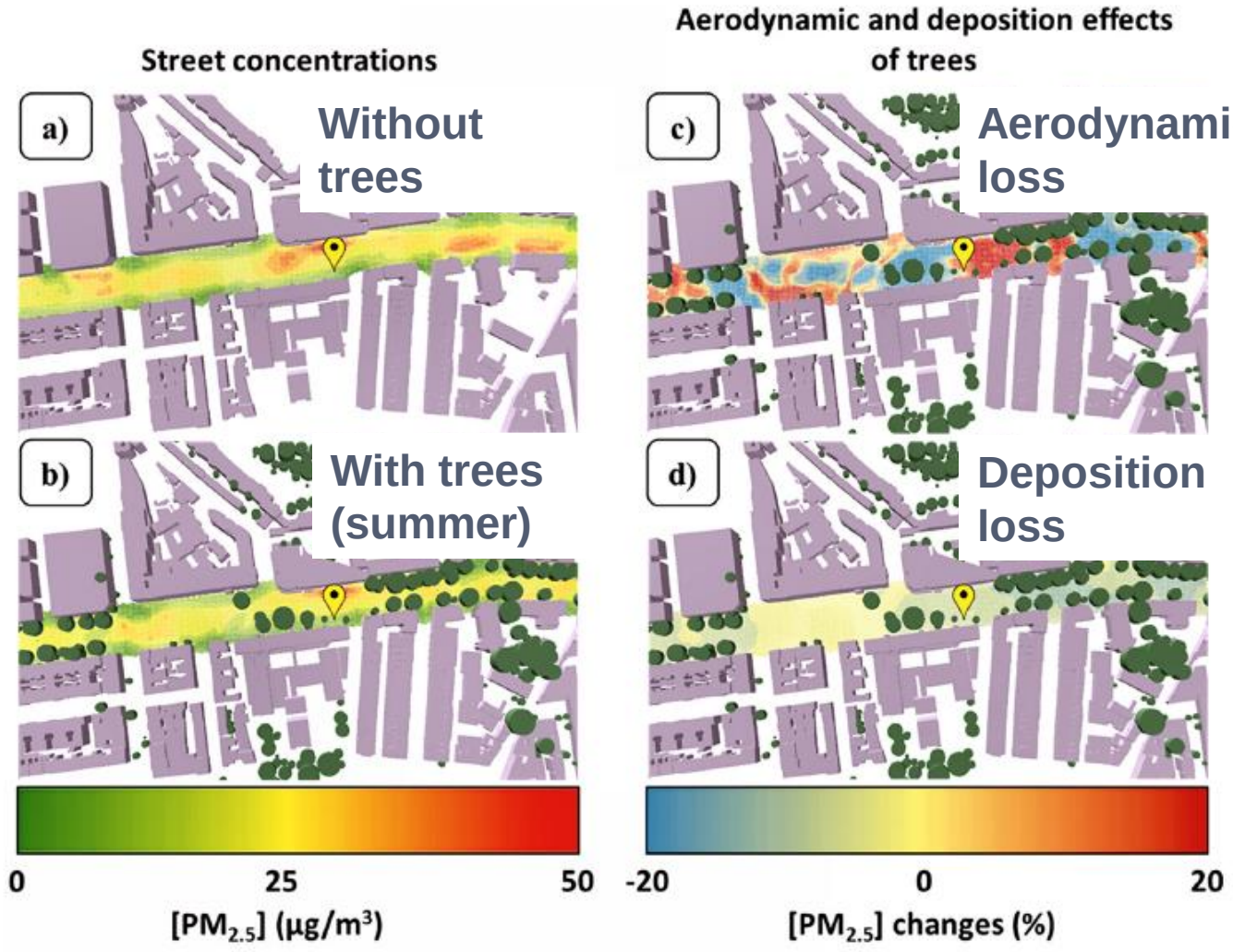


- Locally (tens to hundreds of square metres) tree planting may enhance or reduce dispersion; this **redistributes pollution but does not remove it**
- Where **vegetation acts as a barrier close to a source**, concentrations immediately behind the barrier owing to that source are reduced typically by a factor of about 2 relative to those which would occur without the barrier, whereas on the source side of the barrier concentrations are increased.
- Tree planting ***may also exacerbate the build-up of pollution*** within street canyons by reducing air-flow

Barriers



Abhijith et al., AENV, 2017



Jeanjean et al, 2017, Urban Forestry and Greening

Marylebone, London

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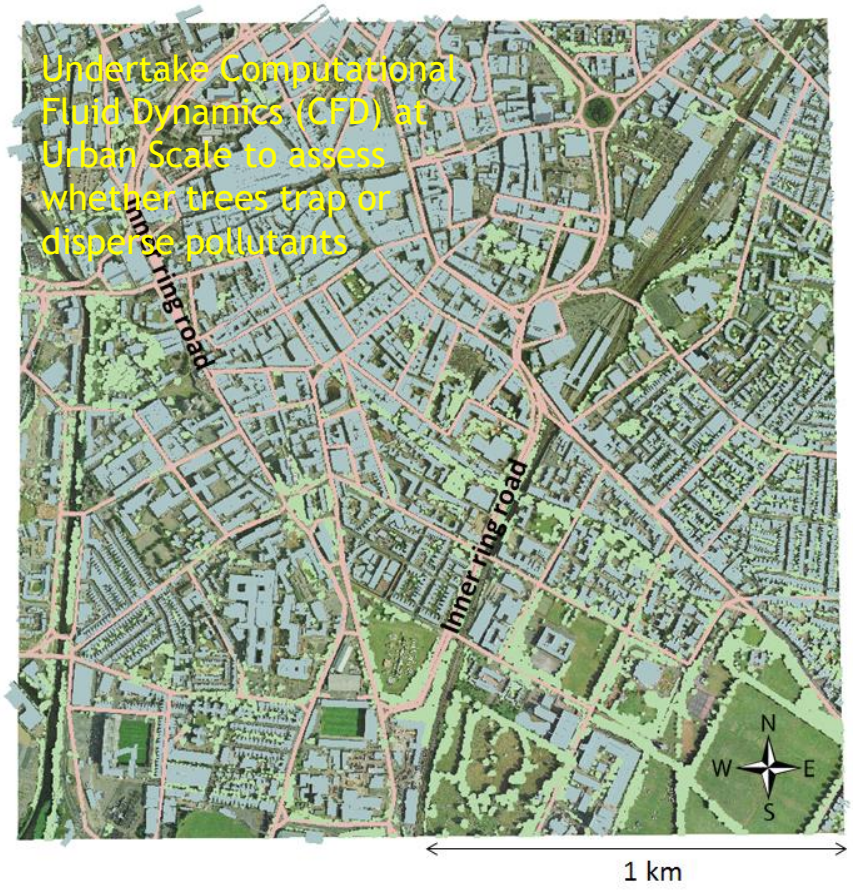
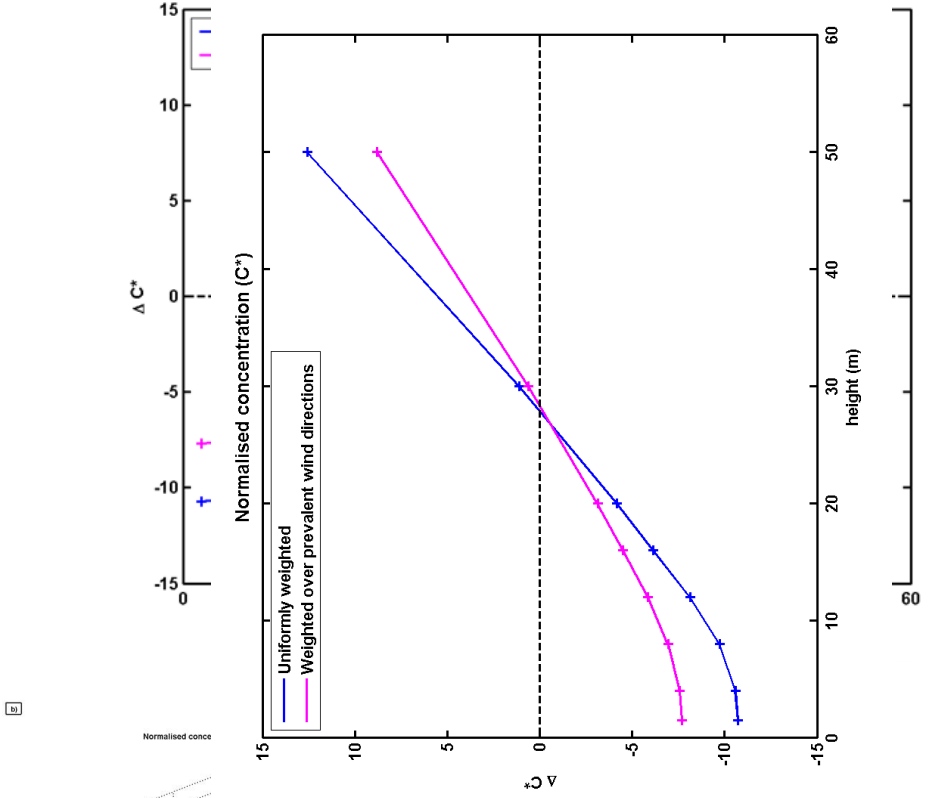
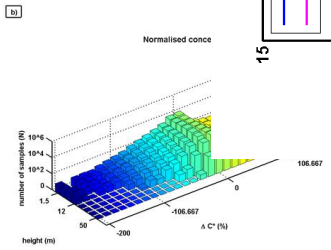
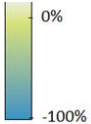
CityScale

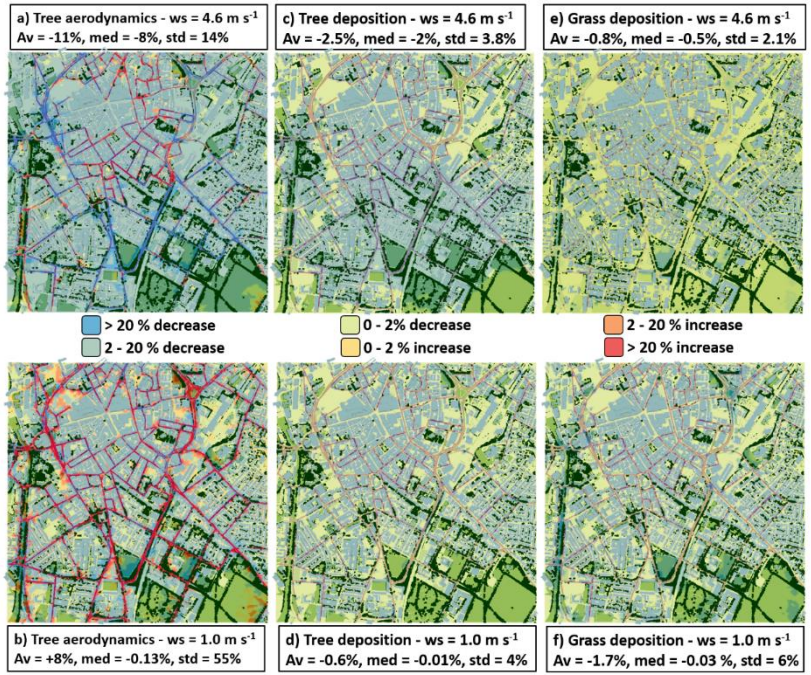

Undertake Computational Fluid Dynamics (CFD) at Urban Scale to assess whether trees trap or disperse pollutants
inner ring road
inner ring road
N
W
E
S
1 km

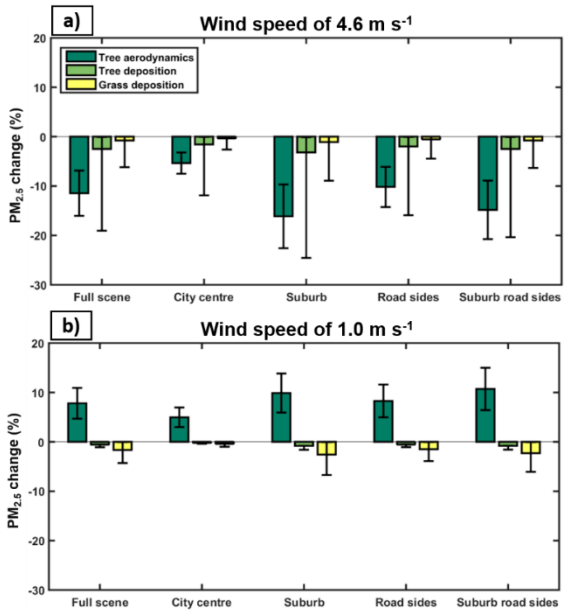

Normalised concentration (C*)
Uniformly weighted
Weighted over prevalent wind directions
height (m)
Δ C*




0%
-100%

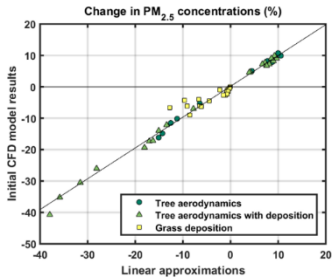
Trees & Grass at a City Scale





Empirical Equation Derived

$$\Delta PM_{2.5}(\%) = X\left(K_{t_1} + K_{t_2}\left(V_{d_{trees}}\right)^{\alpha}\right)$$



Jeanjean et al, Atmos Env, 147, 1-10, 2016

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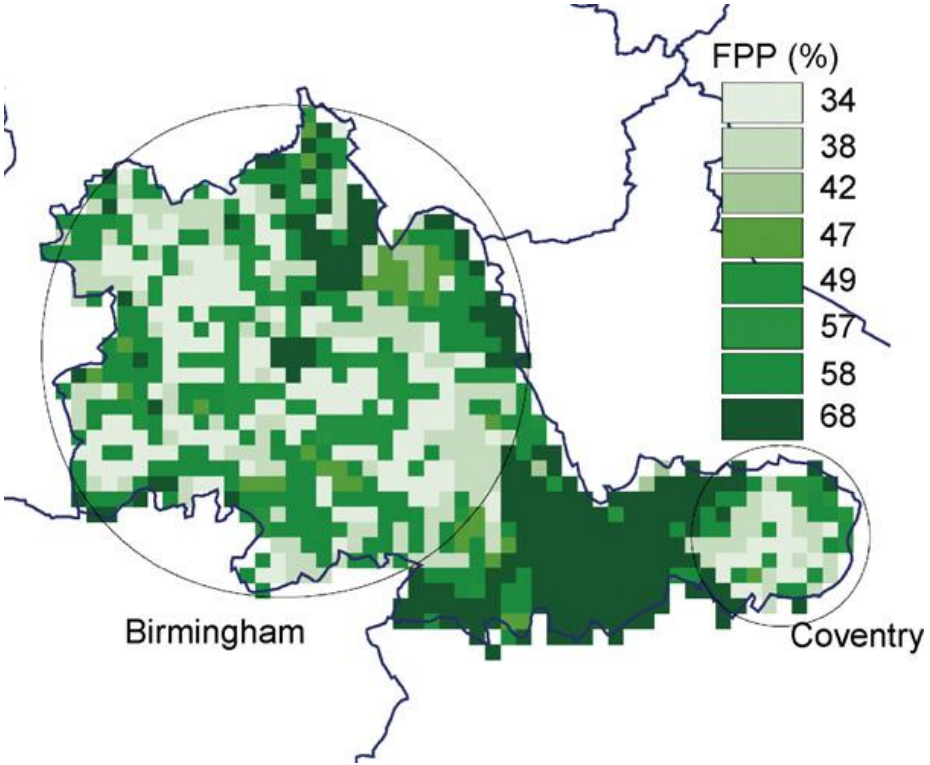
Potential tree planting in the West Midlands

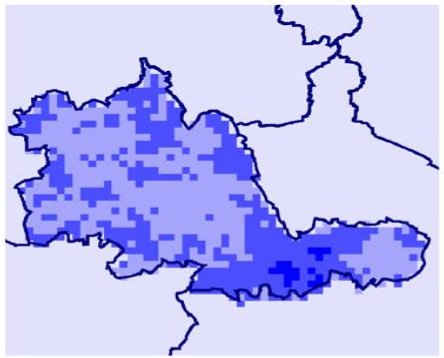


- Dispersion model
- Entire West Midlands conurbation ..Coventry Birmingham
- An extensive survey of vegetation

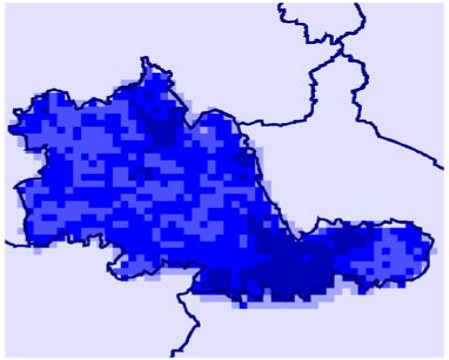
FPP……..Future planting potential
Removal of existing trees
Planting 25% of available space
50%
75%
100%.....all gardens, parks, verges, green space, sports grounds.

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

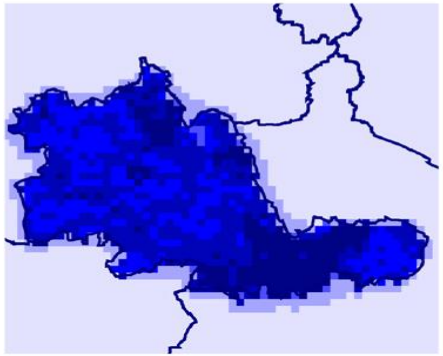
PM_{10} reductions for 4 planting scenarios



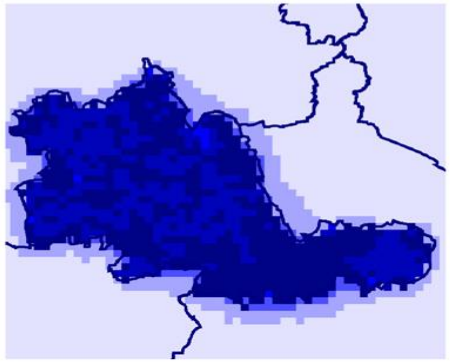
FPP25



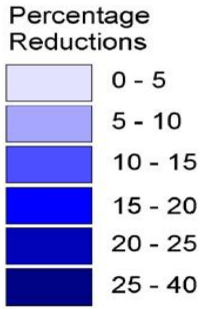
FPP50



FPP75



FPP100



Scenario	%Change
No trees	4%
FPP25	-10%
FPP50	-17%
FPP75	-22%
FPP100	-26%

McDonald et al, Atmos Env. 2007

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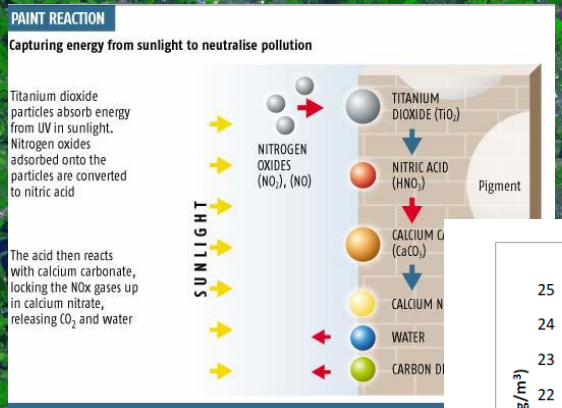
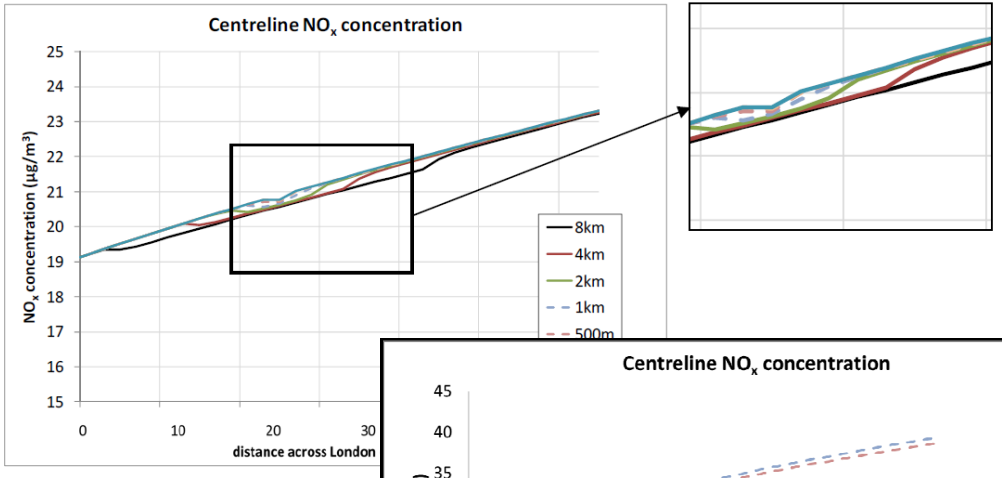


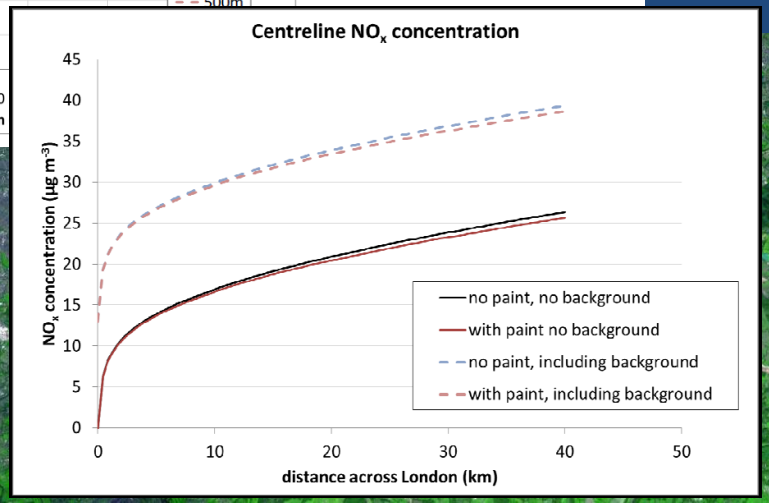
AIR QUALITY EXPERT GROUP

Paints and Surfaces for the Removal of Nitrogen Oxides

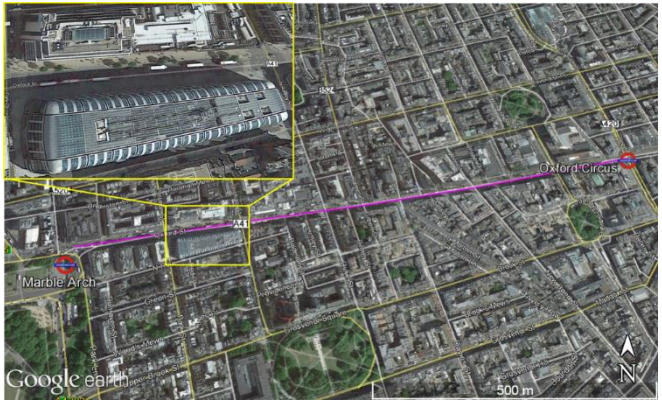
Prepared for:

Department for Environment, Food and Rural Affairs; Scottish Government; Welsh Government; and Department of the Environment in Northern Ireland



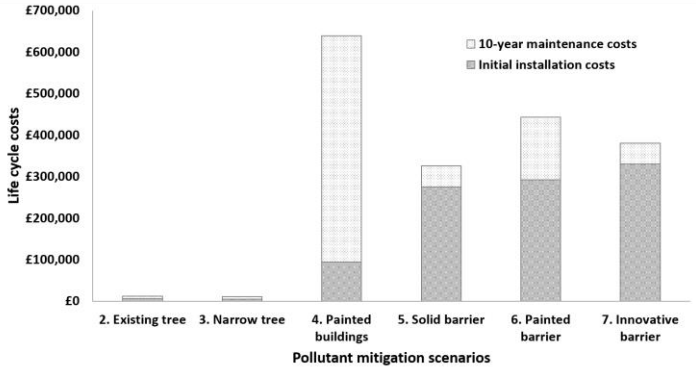


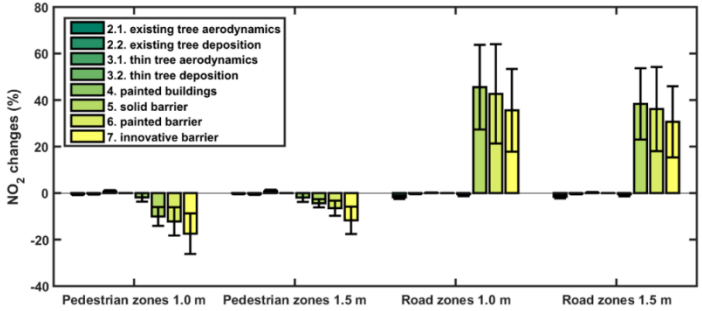
Mitigation in the urban environment – Oxford St, London



Full lifecycle analysis of six mitigation strategies using CFD (Jeanjean et al, 2017)

Mitigation strategy modelled in Oxford St (London, UK)	NO_2 concentrations on footpaths (pedestrian exposure)	NO_2 concentration on the road (cyclist/driver exposure)
Existing tree	✓ 0.9 % decrease	✓ 2.0 % decrease
Narrow tree	✗ 1.0 % increase	✗ 0.3 % increase
Painted buildings (TiO_2)	✓ 0.8 % decrease	✓ 0.4 % decrease
Solid barrier	✓ 4.4 % decrease	✗ 38.3 % increase
Painted barrier (TiO_2)	✓ 6.5 % decrease	✗ 36.1 % increase
Innovative barrier	✓ 11.7 % decrease	✗ 30.6 % increase





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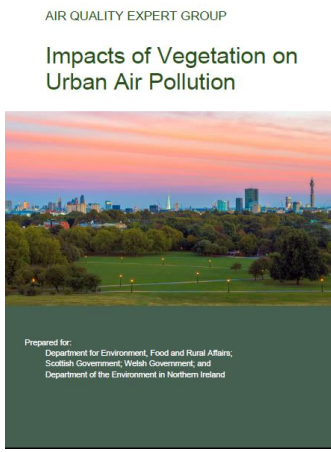
CONCLUSIONS



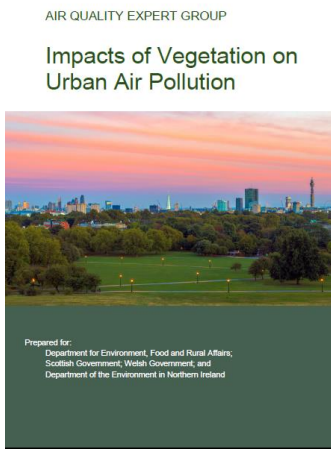
- **Overall, vegetation and trees in particular are regarded as beneficial for air quality, but they are not a solution to the air quality problems at a city scale.**

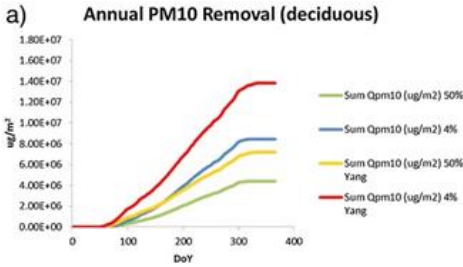
- It is unlikely that large reductions in concentration (>20% for $PM_{2.5}$) could be achieved using vegetation to enhance deposition over a substantial area.

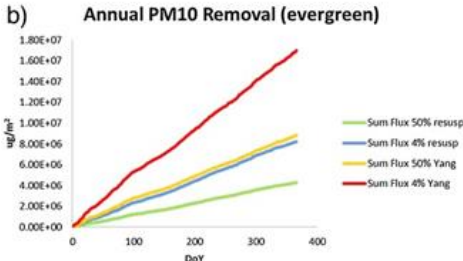
- For nitrogen dioxide (NO_2), vegetation is, generally speaking, of little benefit; it is not a very efficient sink. The deposition occurs in daytime, and primarily in the warmer months, when NO_2 is less of a problem.

Other things …

- The use of trees to improve air quality is not without negative impacts as some tree species are important sources of biogenic volatile organic compounds (BVOCs), notably isoprene.
- However, BVOC emissions could be avoided by selecting low emitting species.
- Similarly, the choice of plant species which are known sources of aeroallergens should be avoided.







Important Paradigm for Air Quality

- Compared with emissions control at source, removing pollutants once diluted into the atmosphere is challenging because of the large volume of air into which the pollutants have been dispersed compared to the surface area to which any potential abatement technology may be applied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